THE

JOURNAL OF ECONOMIC BIOLOGY

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VOLUME III.

1908.

LONDON:

DULAU AND CO., 37, SOHO SQUARE, W.

1908.

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JOURNAL OF ECONOMIC BIOLOGY.

THE BIOLOGY OF POLYSTICTUS VERSICOLOR (Fries).

By

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With Plates I and II.

Contents.

1.—Introduction.

Polystictus versicolor (Fries) is one of the numerous fungi which cause the rotting of wood. Its small fruit bodies are to be found during most months of the year on dead logs lying in moist situations; but under the climatic conditions of England it is especially during the autumn months, and thence onward to late spring, that they appear in great abundance. The fungus is one of the most familiar objects to the field mycologist, but its life-history and ecology seem, hitherto, to have been neglected (Pl. I, fig. 1).

The tough, leathery, neutral-tinted and velvety-topped fruit bodies or sporophores are never more than 4 or 5 cms. across, and unless occurring in great masses form quite inconspicuous objects. These horizontally projecting bracket-like sporophores, semi-circular in form, are of the dimidiate type, being attached to their woody host

by a broad surface; and sometimes, when climatic conditions are favourable, owing to their densely imbricate manner of growth, their broad attaching bases meet and unite, and then whole sheets, even to a square foot or more in area, may be stripped away from the substratum.

The upper surface of the pileus is slightly depressed behind, and since it is covered with fine hairs looks and feels like velvet; a concentric zoning (Pl. I, fig. 9) of various neutral-toned green, yellow, grey, brown and buff bands is always more or less noticeable: the smooth, flat hymenial surface is white at first, but changes to a deep cream colour, and on drying often presents a bright sheeny appearance. When the fungus grows on the rounded top of a horizontal log, specimens of sporophores resembling an umbrella-shaped species with an almost sessile pileus are frequently found, since in such a position a lateral outgrowth is able to extend from every side of a short stem-like base: also on the sides of nearly vertical logs a form almost resupinate, with the hymenial tubes for the most part reduced to mere grooves, is not uncommon.

The fungus is a pure saprophyte, whose natural habitat is moist dead wood: it seems highly probable that it will grow on almost any kind of wood except that of conifers.

I have found it growing on *Quercus robur*, *Fraxinus excelsior*, *Pyrus aucuparia*, *Salix alba*, *Betula alba*, *Pyrus malus*, *Ligustrum vulgare* and *Crataegus oxyacantha*, and have been able to infect without difficulty small blocks of *Fraxinus excelsior*, *Ulmus campestris*, *Prunus avium*, *Alnus glutinosa*, *Acer pseudoplatanus*, *Aesculus hippocastanum* and *Betula alba*, and have successfully cultivated the fungus from spore to spore.

2.—Spores and their Germination.

If a fresh fruit body is placed on a glass slide or paper a plentiful supply of spores is obtained in the course of a few hours: they are best seen macroscopically on black paper, where the numerous little white heaps look like an imprint of the hymenial surface of the sporophore.

Microscopic examination shows each spore to be a colourless oval unicellular body, 5-6 × 2μ, in the protoplasm of which can be distinguished two, or sometimes three, groups of granules (Pl. II, fig. 1).

The spores germinate very readily in ordinary tap water, or even distilled water. Within eighteen hours, at a temperature of 19° C., nearly all become swollen, and quite 50% produce germ tubes, 1, 2, 3, or 4 times their own length, and within three days all will germinate.

The germ tube arises at any position of the spore; sometimes abruptly; but more often it seems merely a gradual tapering prolongation of the spore wall: two germ tubes are frequently put forth, and occasionally, before a germ tube is protruded, a division wall is formed across the swollen spore (Pl. II, figs. 2 and 3).

Germination is not influenced by the presence or absence of light.

2a. Hanging-Drop Cultures.—In order to observe the further development of the germ tube, and the formation of a mycelium, hanging-drop cultures were made, due precautions being taken to use well sterilized apparatus and culture media. Spores were collected upon sterilized paper on glass slides, and were introduced into the culture by means of a sterilized platinum wire. Since a mere touch of the platinum wire will convey hundreds of spores to a drop, when only a few spores were wanted a series of fractional drop dilutions was made on cover glasses, until at last a dilution was obtained from which cultures containing about 5 or 6 spores each could be made.

The culture media used were distilled water, tap water, 8 per cent. gelatine, 12 per cent. cane sugar, 6 per cent. cane sugar, sections of oak, sycamore, cherry, ash, 5 per cent. witté peptone, 5 per cent. alcohol, vaseline, filter paper, 4 per cent. glycerine, thin boiled starch paste and malt extract solidified with 10 per cent. gelatine.

The malt gelatine afforded a good culture medium. In it spores germinated within thirty-six hours, and within two days produced long narrow septate hyphae rich in protoplasm. The progress of the hyphae was rendered very conspicuous by the gradual liquifaction of the gelatine in their vicinity. After seven or eight days the protoplasm in the hyphae commenced to break up into lengths, separated from one another by empty spaces; and later these protoplasmic lengths again broke up into very short rod-like cells (Pl. II, fig. 4) which are no doubt analogous to the rod-like gonidia observed by Brefeld[1] in the young mycelial hyphae of many *Coprini*, and to the oidia which Falck[2] describes as forming a stage in the life-history of *Collybia tuberosa*, *Hypholoma fasciculare*, and other Hymenomycetes, and again which Buller[3] found to occur in *Polyporus squamosus*.

Several of these rod-like oidia were transferred to other hanging-drop cultures; they germinated immediately, and produced a mycelium, which about the seventh day broke up into oidia just as the mycelium from the spore did. This oidial formation continued for

[1] Brefeld, quoted from De Bary, Fungi, Mycet. and Bact. (Eng. Ed.), 1887, p. 332.

[2] Falck, Beitr. z. Biol. d. Pflanzen, 1902, Bd. viii. Die Cultur des Oidien und ihre Rückführung in die höhere Fruchtform bei den Basidiomyceten.

[3] Buller, Journ. Econ. Biol., 1906, vol. i, p. 117.

two or three months, after which all the oidia grew out into long thin branching hyphae, among which clamp and H connections were frequent. By the end of another three months the hanging-drop appeared to be drying up, and the mycelial development looked very exhausted, and poor in protoplasm, and contained numerous large bright refractive drops—no doubt oil drops. At this stage the hyphae in many places became much wider and formed large rounded cells, some with a lining layer of protoplasm surrounding a bright refractive drop, others remained empty: this stage was followed immediately by a budding process: small bud-like branches were developed from these large cells, and after the formation of a division wall, cutting them off from the main cell, became free; or these bud-like branches remained attached and cells were budded off from them (Pl. II, fig. 5). These conidia-like cells also had a protoplasmic lining, and contained a large glistening drop. Here again there is a strong resemblance to the conidial and yeast-like forms of oidia which Falck[1] observed occurring in the exhausted cultures of *Collybia tuberosa*. These oval conidia increased in size and then budded again or a division wall was formed across the cell previous to the budding: sometimes the budding went on so quickly that a chain of cells was formed just as is found in actively budding yeast. To one culture containing numbers of these conidia a minute drop of malt wort gelatine was added, and within a few days a rich mycelial development was formed, and within nine days the protoplasm in the hyphae had begun to divide up into short lengths, just as in the first mycelium from the spore. A few of these conidia were transferred to malt gelatine drop-cultures: with some the budding only continued, others put forth germ tubes which became septate, increased in size, and then gave off buds (Pl. II, fig. 6): these buds were much larger than those of the exhausted culture, more often double-celled, were richly protoplasmic, and without a large central glistening drop, although small oil drops were to be seen. These oidia when budded off were colourless, but gradually assumed a pale olive green tint, and sometimes before germinating they surrounded themselves with another cell wall, which had an irregular outline (Pl. II, fig. 6*d*). A similar budding process was observed in a distilled water hanging-drop culture containing many spores, when it was moistened again after having dried up within forty-eight hours of being made, at the stage when many spores had swollen, and just a few had put forth very short germ tubes. Here again the conidial form seems to have arisen owing to starvation.

[1] Falck, *l.c.*

Cultures in 4 per cent. glycerine and boiled starch paste behaved very similarly to one another. The spores swelled very much and produced very wide germ tubes which became septate: at intervals one or more cells in succession became much swollen, some contained protoplasm, others remained empty; sometimes the ends of short branches swelled out into large round cells (Pl. II, fig. 10). A similar arrangement of enlarged cells intercalated in the hyphae were seen in the mycelium inside a pitted duct of mountain ash wood in a very advanced stage of decay, and again it occurred very frequently along the hyphae on an ash culture, which for no apparent reason was not thriving as other ash cultures usually did, and also on a poor culture of horse chestnut.

Both 8 per cent. gelatine and 5 per cent. witté peptone were quite as good media as malt extract solidified with gelatine: in cane sugar (12 per cent. and 6 per cent.) the spores died, apparently owing to plasmolysis: no germination took place in 5 per cent. alcohol or in vaseline: in 5 per cent. glucose the spores germinated within twenty-four hours.

The cultures in which were placed minute chips of oak, sycamore, cherry, ash and alder did not prove very successful: the spores germinated and produced a poor mycelium, whose hyphae could be distinguished penetrating walls or going through pits. These cultures stopped growth after a few weeks; nor was insufficient aeration the cause, for occasionally and momentarily raising the cover glass brought about no further growth.

In the cherry chip culture the mycelium was chiefly produced in the pitted vessels of the chip: a brown resinous substance, probably some degradation product, made its appearance also.

No chemotropic stimulus could be attributed to the wood, for germ tubes continued to grow in whatever direction they started growth, no matter the position of the chip.

2b. Flask and Tube Cultures.— Cultures in flasks and test-tubes, filled to one-fourth their depth with 8 per cent. gelatine, were observed for six months. The fungus behaved just as in the hanging-drop cultures: the gelatine was gradually liquified, and presented a white cloudy appearance; beginning first at the surface, where the infection was made, and progressing downwards. After two months all the mycelium had broken up into oidia; four months later the oidial form had passed over to the mycelial form, although a few oidia were still to be seen. Each culture after being examined was attacked by *Penicillium*, and so had to be discarded.

Flask cultures using 4 per cent. glycerine were under observation

for more than twelve months, but only an extremely spare growth of mycelium appeared. This mycelium was similar to that seen in the hanging-drop cultures, that is, many of the hyphae were abnormally wide and very vacuolate, and large rounded cells containing a bright glistening drop were frequent: it seems very probable that these abnormal hyphae are merely involution forms, due to 4 per cent. glycerine being an unfavourable culture medium (compare page 3). After nine months numerous black spots were visible in the mycelium: microscopic examination showed that these were centres at which olive green conidia (Pl. II, fig. 10) were being budded off from, or intercalated in, the hyphae of the mycelium: these conidia were similar in appearance and behaviour to those previously mentioned as occurring in exhausted hanging-drop cultures, and like them when transferred to small wooden block cultures were capable of infecting and thriving on the wood. In the malt gelatine flask and tube cultures a luxuriant growth of white mycelium appeared, which in four weeks liquified the whole of the culture medium (3 cms. deep): but here the mycelium formed a dense felt-work on the top of the liquid, instead of permeating the whole of it as in the gelatine cultures: also, in marked contrast to the continued oidial formation seen in the gelatine cultures, no oidial development could be detected. No sporophore formation appeared; but after eight months numerous small round black patches, 2 or 3 mm. in diameter, appeared on the surface of one culture, and when these were examined microscopically they proved to be centres at which were being budded off olive green conidia, similar to those already mentioned. The frequent occurrence of olive green conidia suggests that perhaps this stage of the fungus may be identified with some species of the genus *Cladosporium*—one of the Hyphomycetes.

2c. Wood block Cultures.—Cultures were made on small blocks of wood (3.5 cm. × 2.9 cm. × 2 cm.), cut from large blocks of heart wood of oak, ash, alder, horse-chestnut, larch, pine, mountain ash, birch, elm, and sycamore.

The method used was that devised by Marshall Ward[1] for cultures of *Stereum hirsutum*: the blocks, after being soaked in cold water for a few hours, or boiled for a short time, in order to be made thoroughly sodden, were placed in short glass cylinders (15 cm. × 3 cm.) plugged at each end with sterilized cotton wool (Pl. I, fig. 11). After heating three times in a steam sterilizer, they were then placed upright in large glass beakers; the upper plug was momentarily re-

[1] Marshall Ward, On the Biology of *Stereum hirsutum*. Phil. Trans. Roy. Soc., 1897, vol. 189 B, p. 123.

moved, and spores from a spore deposit were transferred to the block by means of a sterilized platinum wire. In the *Stereum hirsutum* cultures of Marshall Ward, instead of spores, mycelium from a gelatine culture was transferred to the culture block. The cultures were kept moist by pouring a few cubic centimetres of tap water into the beaker supporting the cylinders: the lower plug in this way was kept continually moist, and although the water used was not sterilized the cultures generally remained quite free from pollution by bacteria and other intruders. If the infection was successful, after about six or seven days a trace of white mycelium could be seen on the outside of the block; and this, extending in all directions, gradually produced a thin white felt-work, varying in thickness from a mere film to two or three millimetres; but only in very few cultures during nineteen months did it quite hide the wood substratum. Growth was best at a temperature of about 15° C.

Ash, mountain ash, horse chestnut, sycamore, and birch were very readily attacked by the fungus, but alder, elm, and oak proved far more resistent, and often only after several attempts did these blocks yield to infection, and even then the fungus did not seem to thrive well. Larch and pine, and any wood protected on all sides by bark, resisted all efforts at infection: spores germinated on the blocks, and a filmy patch of mycelium could be distinguished after seven days, but there was no further growth. Spores would not germinate on blocks which had been soaked for a week in creosote. Three months after infection one or two very small creamy waxy-looking hemispherical bosses, covered with short hairs, usually made their appearance on the ash, sycamore, horse chestnut and birch blocks, and colourless or yellow watery faintly acid exudations were frequently seen either on the bosses or near: some of the bosses attained a height of 4 mm., but more frequently were smaller. Occasionally the bosses extended, and so formed ridges, 6 or more mms. in length, with a height of $1\frac{1}{2}$ mms. Often, after a few weeks, these bosses and ridges turned brown, and no further development took place. Other bosses appeared, and this continued for months, and still there were no signs of a typical bracket form of fruit body; although it seemed highly probable that these bosses were efforts at fruit formation, since they were so very similar to the initial stage of a sporophore boss formed under natural conditions.

Several of the blocks were removed from the cylinders into more spacious sterilized damp glass chambers and placed either on cotton wool or sand, and in as bright a light as it was possible to obtain in the laboratory. This environment seemed a little more favourable, since

the next bosses that were formed were slightly larger, and here and there a boss developed with a depression just at the lower side of its apex, thus resembling the second stage of the sporophore formed under natural conditions (Pl. II, fig. 12*b*). This went on for five or six weeks, and still no true bracket form appeared. The covers were now left off the chambers, and no attempt was made to keep the cultures under sterile conditions.

It seemed very probable that as the cultures were so small an insufficient supply of nutriment might be the cause of no proper fruit formation; so two of the culture blocks (ash and elm) were bound to large unsterilized blocks of the same wood, and placed in large glass damp chambers, while several others were placed out in the open among herbaceous plants, a fairly shady spot being chosen, since the time of the year was August. The large block with the culture of ash attached became infected within a few days, and within a month showed a luxuriant growth of mycelium creeping over it, radiating out in all directions, even to a distance of 5 or 6 cms. Its fan-like spreading mycelium greatly resembled a rich mycelial growth of *Merulius lachrymans*, but without the conducting strands so characteristic of the latter fungus. As yet no sporophore has appeared, and seventeen months have elapsed since the culture started, and nine months since it was attached to the large block. The block with the elm culture attached shows no external signs of infection. But the cultures which were put out in the open, under natural conditions, quickly responded to the change of environment, and one small newly-formed cream wax-like boss appeared on each of the three cultures, and on an ash block there appeared within ten days a very small bracket-shaped sporophore, measuring 7 mm. across, which showed all the characteristic features of *Polystictus versicolor*, and shed spores; and this was seven months after the infection of the block (Pl. I, figs. 2 and 3). It seems probable, therefore, that in nature this fungus can develop from the spore to the fruit body stage in the course of a single season.

On the vertical side of the block a resupinate form, with pores shedding spores, was also formed. Microscopic examination of the block showed that fungus hyphae, to a greater or less extent, were to be found in every part; but, nevertheless, on the whole it still remained hard, and there was no great destruction of wood except in the immediate vicinity of the fruit bodies, while there, holes could easily be scraped in the wood with the finger nail.

It may now be concluded that it was not a deficiency in the supply of nutriment, but the unnatural conditions of growth prevailing

in the laboratory, which prevented the formation of the sporophore. On another culture (mountain ash) six and a half months after infection, when it had been two months out in the open, a very small sporophore (5 mm. × 3 mm.) appeared. Lakon,[1] when recently repeating some experiments of Brefeld, found that the sporophore formation of certain *Coprini* was inhibited by a damp atmosphere; but immediately a stream of air was allowed to pass freely through the culture tubes normal sporophores developed.

On the upper horizontal surface of an ash block, infected about the same date, there appeared a deformed sporophore which shed spores from pores formed on its upper surface. This also had just been ten days out in the open.

Although in all the hanging-drop cultures the mycelium produced from the spore passed through an oidial stage after about eight days, yet only in two instances was any trace of this form found on the many block cultures examined, and even then oidia certainly were not abundant.

Falck[2] considers the oidial form of mycelium as a form especially adapted for living in concentrated solutions, and the ordinary basidial mycelium as a form adapted best for growing on solid substrata, owing to (1) its especial power of dissolving the most resistent plant products, (2) its capacity for absorbing dilute solutions, (3) its conducting power. The culture experiments which have already been described certainly support this view, for in the hanging-drop cultures it was only when a lowering of the concentration of the drop took place, owing to the absorption of food material, that the oidial form passed over into the ordinary mycelial form: in the instances mentioned of oidia appearing on the block cultures, possibly the blocks were unusually sodden, and the spores germinated under conditions similar to those of a hanging-drop.

Some of the olive green conidia from a gelatine culture, and also from a glycerine culture, were transferred to a block: soon the whole of the exterior became covered with green conidia, and from some of these were formed hyphae (green and colourless) which penetrated the wood.

An attempt was made to infect branches of two living trees (birch and apple). A wedge-shaped slit was made in each branch, and a plentiful supply of spores then introduced and the slit bound up. Other branches, after being slit and bound up, were kept as controls. After

[1] G. B. Lakon, Die Bedingungen der Fruchtkörperbildung bei *Coprinus*, Bot. Zeit., Abt. 2, 16th Jan., 1908, p. 25.

[2] Falck, *l.c.*

four months these branches were examined. The spores had germinated, and had produced a very poor mycelial development, but had not penetrated the tissue; except in the case of the birch, where in several of the vessels close to the cut surface involution forms of hyphae had developed.

3.—Destruction of Wood.

On all the wood cultures, after a few weeks, the infected areas could very easily be distinguished by a change in colour which took place; for the progress of the mycelium is marked by its bleaching effect. This is very striking on the dark woods of elm and alder and cherry, but even the white wood of ash takes a paler hue. In this production of a "white rot" it somewhat resembles *Polyporus juniperinus*[1] and *Polyporus squamosus*.[2] Wood rotted by *Polystictus versicolor* is eventually so soft that a blunt knife will easily penetrate it, and by slight pressure between the fingers it crumbles up and looks like sawdust. If a piece be broken out of a large block and examined, it is seen that it readily splits into tangential flakes parallel with the annual rings, and that these flakes easily break up again into very small splinters parallel with the long axis of the log. The very white lines and small patches, seen especially on the surface of the flakes, are due to strands of white mycelium.

To gain more minute detail of how the fungus proceeds in its work of destruction the small wood culture blocks and also wood from very rotten logs were examined microscopically. Transverse and longitudinal sections soon revealed that the pitted ducts and medullary rays are the first objects of attack: the plugs of fine hyphae filling the vessels are well shown, both in transverse and longitudinal sections, and even in young cultures, on the dark wood of elm and alder, these could be traced with the naked eye as long white lines in the wood. The splitting of the wood into tangential layers parallel with the annual rings is now explicable, since it is in the spring wood that pitted ducts are most abundant, and thus this direction would prove the line of least resistance to fracture. A similar manner of fracture due to the same cause is seen in wood rotted by *Polyporus sulphureus*.[3] The gradual disappearance of the medullary rays is best

[1] Von Schrenk, U.S. Dept. of Agric., 1900, Bull. 21. Two diseases of Red Cedar caused by *Polyporus juniperinus*.

[2] Buller, *l.c.*

[3] Von Schrenk, U.S. Dept. of Agriculture. Some diseases of New Eng. Conifers, Bull, No. 25, 1900.

seen in longitudinal tangential sections (Pl. II, fig. 8*a*), where all stages can be found, beginning with the initial one of corrosion of the walls, to the final stage of nearly a lenticular hole. In later stages the fibres round the vessels and medullary rays are also attacked, and signs of corroded walls riddled with holes, formed by the penetration of the fungus, are everywhere evident (Pl. II, fig. 8*c*). In the final stage the thickening layers of the walls of the fibres are almost entirely consumed, leaving only the middle lamella (Pl. II, fig. 7*d*); and cell contents everywhere are quite wanting. In all directions fungus-hyphae are to be seen ramifying everywhere and perforating walls, sometimes passing through the pits, though absence of these is no hindrance to the penetration of the walls (Pl. II, figs. 7, 8, and 9): in some places there was observed a swelling of the hyphae previous to the perforation of the cell wall (Pl. II, fig. 9), as if a storing of energy had taken place previous to the attack. Francz Drysen [1] notes among the Discomycetes a similar swelling of hyphae previous to penetrating walls, also Miyoshi [2] mentions the occurrence of a similar phenomenon during the penetration of a collodion membrane by *Botrytis cinerea*.

In two very rotten specimens (apple and mountain ash), from branches varying from 6 inches to 1 foot in diameter, a dark brown line marked the limits of the ravages of the fungus: it was due to the presence of brown oily-looking cell contents, probably decomposition products of a resinous nature, although only negative results were obtained when tests (Cu acetate solution, Ferric chloride solution, Rosaline violet and Am. molybdate and AmCl) were made for resin and tannin. This dark brown line, although similar in appearance to the black layer found in wood rotted by *Polyporus squamosus*,[3] or by *Trametes pini*,[4] is not of the same nature, for the latter is formed of mycelial tissue: but it bears a strong resemblance to the brown layers so often seen in transverse sections of sound wood taken from well-pruned fruit trees, which is said to be due to oxidation products; since pruning probably allows a freer access of air to the interior of the stem. Similarly wood penetrated by mycelium would doubtless receive a very abundant supply of air, hence the boundary limiting the attack of the fungus might well be defined by brown oxidation products.

[1] Drysen, J. R.M. Soc., Apl., 1907.

[2] Miyoshi, Die Durchbohrung von Membranen durch Pilzfäden, Pringsh. Jahrb., 1895, vol. 28, p. 281.

[3] Buller, from a paper in preparation for the press.

[4] Von Schrenk, U.S. Dept. of Agriculture, 1900, Bull. 25.

The fungus hyphae are unable to penetrate bark except at the lenticels; hence it is always at a lenticel or place of injury that the first sign of the formation of a sporophore appears; and the bark is so resistent that it is quite possible to obtain a branch which has been rendered nearly hollow, owing to the consumption by the fungus of nearly all the interior.

The very marked change in specific gravity is apparent on handling the rotten wood, which, like most woods well rotted by fungi, feels particularly light in weight. The specific gravity of a block of dry mountain ash changed from .5 to .1, and of dry birch from .65 to .2.

4.—Chemical Changes in Rotting Wood.

It is very evident that side by side with these structural alterations great chemical changes take place in the composition of wood. The usual colour tests of phloroglucin and chlorozinc iodine were applied to microscopic and larger portions of sound and decayed wood. With phloroglucin and HCl the rose-red colour was certainly far less pronounced in the rotten than in the sound wood, and in wood in the last stages of decay, whatever fragments of medullary rays did remain were only very faintly stained; so this is evidence that the fungus removes to some extent the substances, whatever they may be, which cause the so-called lignin reaction. With chlozinc iodine all the elements of both sound and rotten wood stained a beautiful golden brown: now although it might be said, judging from the phloroglucin test, that delignification had taken place, yet no violet colouration indicating the presence of uncombined cellulose could be detected. A few very faint traces of violet colouring were to be seen in fragments of medullary rays of rotten wood after staining for forty-eight hours. Although the substance hadromal, which was first isolated by Czapek,[1] gives the phloroglucin reaction, yet it does not seem quite justifiable to infer that the absence of colouration on applying the phloroglucin test is conclusive evidence that that aromatic aldehyd has been abstracted by the fungus; since many other aromatic compounds have a similar reaction with phloroglucin and HCl.

Also knowing that some unlignified cell walls give the phloroglucin test this colour reaction is hardly a conclusive proof of the presence or absence of lignification. Since colour tests cannot be relied upon, the difference between altered and unaltered wood can hardly be satisfactorily explained without actually isolating and estimating

[1] Czapek, Biochemie der Pflanzen, vol. i., p. 571.

quantitatively the different substances composing the woody tissue - a by no means simple task even in the hands of an experienced chemist, since on the subject of a chemical nature of wood there are still very many differences of opinion. A reference either to Czapek's [1] or Wiesner's [2] summary of the subject, shows that although many substances have been isolated, concerning some it is a matter of much uncertainty whether the substance existed as such in the wood or was merely some compound formed during the chemical reaction.

Von Schrenk,[3] in the course of his investigation of the red rot caused by *Polyporus annosus*, obtained by abstracting finely rasped cedar wood with absolute alcohol for six hours in a Soxhlet's extractor, a substance which he considered identical with hadromal.

Similar extractions were carried out, using finely divided sound and decayed wood. 5.4 gms. of sound fine birch sawdust was extracted with 150 cc. of absolute alcohol for nearly sixteen hours: the extract when tested with phloroglucin and HCl assumed the deep rose red colour characteristic of lignin, and also of hadromal, and when evaporated down left a brown gummy deposit, in which, when examined microscopically, could be seen a few white transparent needle shaped crystals, which may have been those of hadromal.

When this experiment was repeated, using decayed instead of sound birch, the extract did not give the phloroglucin reaction, although on being evaporated down a similar gummy deposit remained.

Since according to Potter [4] some of the delignification of wood attributed to fungi has really taken place during the sterilizing process, it was thought well to see to what extent this might possibly have been the case in the small blocks such as were used for the wood culture experiments. 5.4 gms. of birch sawdust (a little culture block weighed about 5.4 gms.) was distilled with 150 cc. of water for twenty hours: the extract did not give the phloroglucin reaction: it was evaporated down, and the brown gummy deposit obtained was redissolved in 3 cc. of water: this liquid gave a very faint rose-red colour when tested with phloroglucin and HCl. Hence, since steaming of wood in a finely powdered state for twenty hours, produces in the extract after concentration only very slight evidence of delignification, the delignification which would take place in a solid block during sterilization (at most $2\frac{1}{4}$ hours steaming) must be very insignificant.

[1] Czapek, *l.c.*

[2] Wiesner, Die Rohstoffe des Pflanzenreiches, 1900.

[3] Von Schrenk, U.S. Dept. of Agriculture, Bull. 21, p. 17, 1900.

[4] Potter, Ann. of Botany, 1904, On the occurrence of Cellulose in the Xylem of Woody stems.

Spaulding[1] considers that Potter's statement concerning this delignification produced by steaming should generally be modified somewhat.

Since wood is known to contain about 20 per cent. or more of xylan or wood gum, an attempt to extract this substance from sound and rotten birch wood was made. Following the method used by Okmura,[2] 2.5 gms. of sound birch wood sawdust was added to a flask containing 25 cc. of 5 per cent. of KHO solution, and after corking up left untouched, except for an occasional shaking for twenty-four hours: a similar mixture was made, using rotten wood instead of sound: on filtering a clear brown extract was obtained from both flasks, the rotten wood extract being the darker of the two. Both extracts were now neutralized with dilute HCl, until only a very slight acid reaction was perceptible: a copious cream precipitate of xylan came down in the sound wood extract, whereas in the other extract only the merest trace of a turbidity was to be seen. After filtering and drying and estimating the increase in weight of the two filter papers, it was found that the wood gum extracted from the 2.5 gms. of decayed wood was only 50 mgs., compared with 150 mgs. from the sound. Taking into consideration that decay in birch wood brings about a reduction of specific gravity from .65 to .2, the figures showing the amount of wood gum extracted from equal volumes of decayed and sound wood would show a far greater contrast. In a similar experiment, with similar results, alcohol instead of dilute HCl was used to precipitate the wood gum.

It is well known that conifers are exceedingly poor in wood gum, hence possibly to this cause may be assigned their immunity to infection by this fungus: on the other hand birch, which contains as much as 26 per cent. of xylan, falls an easy prey.

5.—THE SPOROPHORE.

The first sign of the sporophore formation is the appearance of a minute rounded white knob, about the size of a pin head, either at a lenticel, crack, or the cut or broken end of a branch: this knob gradually increases in size until it stands out about 4 or 5 mms. from the bark (Pl. II, fig. 12*a*). A horizontal groove (Pl. II, fig. 12*b*) now appears across the apex of the knob, and in the course of the next twenty-four

[1] Spaulding, Missouri Bot. Gard., 17th Report, 1906. Studies on the lignin and cellulose of wood.

[2] Okmura, Imp. Univ. of Japan, Coll. of Agric., Bull. 2, 1894-97. Wood Gum in trees (Xylan).

hours the bracket form is made much more pronounced by the greater growth of the upper half of the knob-like structure forming the pileus (Pl. II, fig. 12*c*): at the same time there is a slight flattening of its upper surface, and on the lower can be seen four or five very shallow pits, which ultimately develop into hymenial tubes (Pl. I, fig. 10): under favourable conditions this stage is reached in five or six days. The part below the groove either ceases growth or extends radially over the bark, and often unites with the bases of other sporophores formed below or at the sides: its exposed surface becomes dotted over with pit-like depressions, which on further growth become grooves: the pileus develops into the semi-circular zoned structure already described, and grows by additions to its margin (Pl. I, fig. 9). At the same time the pits which cover the under surface to within .5 mm. of the margin develop into hymenial tubes: the thickness of the pileus varies from about 4 or 5 mms. behind where the tubes are formed to 1 mm. or less at the margin where there are no tubes. The hymenial tubes vary in depth from 1.5 or 2 mm. to mere depressions: very long tubes, of a depth of even 5 mm. or more, are sometimes formed.

The rate of growth of the pileus varies according to temperature and supply of moisture. With a temperature of 60° F. and a saturated atmosphere—highly favourable conditions for growth—an average of 1 mm. a day is attained: at a lower temperature of 50° F. the average growth does not exceed .5 mm. a day, and at a temperature whose maximum and minimum does not vary much from 40° F. the growth is very slow, 1 mm. in five or six days. During frosty weather growth is entirely arrested. A sporophore takes about six months to complete its growth; but it is difficult to know when this final condition is reached, for growth is often arrested for a month or six weeks at a time when conditions are unfavourable: also injuries by beetles, and probably birds and rodents, who find it a convenient source of food, will cause sporophores to stop growing.

The zoning of the pileus seems due chiefly to an alternate checking or promotion of growth caused by changes in the amount of moisture, this of course being dependent on varying atmospheric conditions. A sporophore-bearing branch of birch was arranged with one end dipping in a few cubic centimetres of water in a beaker; this was placed in a dish also containing a little water, and the whole was covered with a bell jar; the temperature did not vary more than a few degrees from 15° C. Hardly any signs of zoning could be traced on the pilei which developed under these conditions, and the velvety surface instead of having the usual ribbed appearance was quite even. Occasionally the bell jar was left off for an hour, and even this slight

exposure to a drier atmosphere was sufficient to cause a check in the growth, and hence a marked zone in the pileus. Pilei growing on logs in fields and woods were watched and measured at intervals of a few days, and always after a period of drought, during which growth was quite or nearly arrested, a distinct furrow or zone marked the end of the old zone and the beginning of the new: sometimes when the period of drought had been prolonged a week or more, in a vertical radial section through the pileus the division line could be seen, extending nearly to the hymenial surface. When atmospheric conditions were unfavourable to growth, the hairs forming the velvety surface were either exceedingly short or none were developed; hence a period of drought was marked by a furrow. The faint zoning which occurs when apparently there has been no great change in the humidity of the air is doubtless due to the check in growth which takes places at night owing to a fall of temperature.

The colouring, which to some extent intensifies the zoning, is dependent on light: it is due to the presence of a diffuse yellowish pigment, which on exposure to light gradually changes into sepia brown granules. When the sporophore makes its first appearance it is always white, as is also any new growth which takes place at the margin of the pileus: after three or four days a pigment is developed in the hairs which cover the upper part of the sporophore, and also in the surface strands of hyphae from which these hairs arise: these pigment granules cause the hairs and superficial hyphae to vary from buff to dark brown, according to the intensity of light. The sporophores grown in the diffused light of the laboratory, under uniform conditions of temperature and moisture, were a uniform pale buff colour: only very rarely was a zone emphasized by a slight deepening of colour, and any zoning that did occur was only very faintly marked, and could be accounted for by differences of day and night temperature.

Sporophores which developed in the open on the lower side of a huge log, shaded by over-arching trees, also had pale buff upper surfaces; but the zoning was well marked, since the variable atmospheric conditions had been responded to by variations in the growth of the hairs. On the same log the sporophores which grew on the top, and on the under side, where they were exposed to a greater intensity of light, developed quite normally, and the buff colour soon changed to the darker brown shade. If growth is checked rather quickly, the margin of that zone of growth, owing to a deficiency in the formation of pigment, is marked by a lighter band; hence the pilei formed in summer, when periods of drought are more frequent, and growth is

often arrested suddenly, generally have many golden brown bands marking these periods.

This yellow pigment is at first diffused through the sap; but later on, when it changes to the darker sepia brown shade, it takes a granular form, and then the hairs and superficial hyphae have the appearance of thick-walled tubes containing a core of sepia brown granules. It is only the fairly young zones of a pileus which show these conspicuous coloured bands, for ultimately the whole surface acquires the same dark colour; and the banded appearance seen then is due only to the differences of texture presented by the velvety ridges and satiny furrows, which become even more conspicuous when the pileus, on becoming quite dry, has the well-known grey appearance. A pale buff-coloured pileus, when once detached from its host and allowed to dry for some weeks, is incapable of developing the darker pigment when exposed again to ordinary atmospheric conditions.

This dark brown pigment is unaltered by H_2SO_4, HCl, or ammonia, but nitric acid changes the colour to brick red: it is slightly soluble in absolute alcohol.

The green zones so often seen are caused by the presence of colonies of *Pleurococcus vulgaris* [1] and *Stichococcus bacillaris* [1] among the hairs on the surface of the pileus.

The biological significance of these velvety hairs, which also occur on the upper surface of the pilei of many species of fungi, is a matter of doubt. According to Buller [2] they form a kind of capillary system for the purpose of rapidly spreading any drops of water which may fall on the pileus; and certainly a drop of water let fall on a pileus does disperse almost instantaneously. Or, they may be of the same use as the hairs of many xerophytic plants, which are in this way afforded protection against rapid desiccation; and in support of this it may be mentioned that a pileus stripped of its hairy surface dries up far more rapidly than it otherwise would do.

Microscopic examination of a pileus showed that it consisted of a densely-woven felt-work of branching septate hyphae, radiating from the attaching base. At the upper horizontal surface many hyphae became free, and formed the characteristic long pigment-containing hairs: other hyphae grew vertically downwards, and formed the hymenial tubes. Some of the largest hyphae measured 3.7μ in diameter. The hymenial tubes were lined by club-shaped basidia (Pl. ii, fig. 11), from each of which were developed four spores attached to the ends of rather long sterigmata.

[1] Kindly identified by Mr. Geo. S. West, M.A.

[2] Buller, in a communication to the Royal Society, not yet published.

Basidia are produced, and spores shot off from the sterigmata, immediately the hymenial tubes begin to form; the tubes always grow vertically down, so that the openings are usually round, but they may be oval, or even groove-like, if the tubes arise from an oblique or nearly vertical part of the pileus.

6.—REACTIONS OF THE FRUIT BODY TO LIGHT AND GRAVITY.

Light and gravity play a very important part in determining the development and direction of growth of the fruit bodies of many fungi—of *Polyporus squamosus*, *Lentinus lepideus* and others, so that it is not surprising to find that the combined action of the two stimuli is necessary for the formation of a properly formed fruit body in this case also.

Two small branches of birch, with fruit bodies already developing on them under normal conditions, were brought into the laboratory and placed in similar damp chambers: one was placed in the dark room, and the other, kept in the light, was used as a control. The already-formed fruit bodies ceased to grow, and in the course of a month several new ones began to develop on both branches, and in addition, on the control branch a small fruit body developed on the edge of an old pileus. These observations were continued for nine months, and never during that time did a proper bracket form of pileus appear on the branch in the dark chamber. Large numbers of white wax-like bosses, which grew to an abnormally large size, were developed over a long period, and after assuming a creamy or greyish velvet-like appearance ceased to grow (Pl. I, fig. 4). Some of these large bosses were from 1.3 to 1.5 cms. in diameter, and projected out 1.6 cms., while normal ones never measured more than one-third of these dimensions. A few of the bosses became slightly depressed at the apex, but no trace of any pore or tube formation was seen. When this branch was moved into a light chamber new bosses continued to form, but these developed into typical fruit bodies in the course of a few days (Pl. I, fig. 5). None of the bosses which had been formed in the dark grew into pilei, no matter the stage of development at the time of the change from darkness to light. On the control branch the small wax-like bosses developed into small normal bracket-like sporophores, but these were paler in appearance and had their zoning less marked than similar fruit bodies grown out in the open air. This experiment points to light being the controlling factor in determining sporophore production; but then no account has been taken of the action of gravity—the importance of which is seen in the results of the following experiment.

Two small mountain ash branches very similar to the above, bearing normally developed fruit bodies, were arranged horizontally, one on a clock-clinostat,[1] the other as a control. Here an environment more nearly approaching a natural one was secured by allowing the branch on the clinostat to project through a hole in the laboratory window, thus while the clock work of the clinostat was protected, the branch had all the advantages of ordinary atmospheric conditions. To obtain a further and more continuous supply of moisture than the rather exposed, and thus dry, situation afforded, an apparatus was made for allowing two drops of water to fall on the branch every three or four minutes, and this was connected by means of a syphon with a small tank of water in the laboratory. The control branch was fixed to the window woodwork a little below the other, and shared in the falling drops of water. The branch on the clinostat rotated three times every hour, and the experiment was continued for seven months; but never during this period did a typical bracket-shaped fruit body form: small white waxy bosses appeared, which spread irregularly in all directions, and sometimes united with one another: these formed eventually an incrustation over the surface of the branch with a rough irregular surface and curled up edges (Pl. I, fig. 6). The white waxy bosses soon turned cream colour and showed signs of a pore formation on the exposed surface, while the surface next to the bark assumed the velvety zoned appearance so characteristic of the upper surface of a normal pileus; a small piece of the pore bearing part, laid on a glass slide for an hour, yielded a good supply of spores. On the control branch a well-developed series of imbricate sporophores appeared.

Taking into consideration these two experiments, it seems quite evident that the dimidiate form of the sporophore is not to be ascribed either solely to the stimulus of light, nor yet to that of gravity, but to the combined action of both, while it is very evident the formation of pores, and thus of spore production, is a response to the one force only -that of light.

7.—*Polystictus versicolor* AS A XEROPHYTE.

An observation will now be described indicating that the mycelium of *Polystictus versicolor* can retain its vitality for at least four years.

A large branch of privet (*Ligustrum vulgare*) with fruit bodies of *Polystictus versicolor* upon it, collected four years previously, was taken from the Botanical Museum, where it had been kept dry. The temperature to which it had been subjected varied from about 10° C. in the winter to 19° C. in the summer. The branch was sawn into two

[1] Bayliss, Galvanotropism of Roots, Ann. of Botany, 1906, p. 389.

parts, one part with the fruit bodies on it and the other without. The branches were soaked for a day in a large vessel of water, and then placed in a damp chamber (50 cm. × 50 cm. × 50 cm.) and kept watered. In the course of a week the bark became covered with a mycelium: this belonged to various moulds, which on fruiting were identified. Just under a month from the date of soaking a number of small cream-coloured wax-like bosses appeared, studding the surface of both branches; from many of them hung pale yellow watery exudations, faintly acid to litmus. After a week or two several projected as far as 6 or 7 mms. from the bark, and also showed indications of the bracket form of pileus characteristic of *Polystictus versicolor*; but on reaching this stage these imperfect sporophores turned brown and ceased growth: these were followed by other similar wax-like bosses, which on reaching the same stage also died. One of the branches was now put out in the open on damp moss, and in a few weeks normal dimidiate sporophores developed on it. The branch left in the laboratory, in about three months from the date of its removal from the museum, produced an abnormal bracket form of fruit body with pores on the upper surface; also another strange-looking structure—a series of five or six undeveloped brackets, growing one out of the other, and projecting like a rod (Pl. I, fig. 8). The light in the laboratory in which these were growing is not good in the darker months of the year, so this may account to some extent for these abnormalities; a few weeks later, as the days grew lighter, in February, a proper typical well-developed sporophore, with concentric zoning, velvety surface and tubular hymenium appeared (Pl. I, fig. 7). It is very evident that the mycelium of *Polystictus versicolor* must retain its vitality after prolonged and continuous desiccation: in the above instance, in four years the mycelium had not died. The contention might be raised that stray spores of *Polystictus versicolor* on the bark had germinated, and in this way the branch had been reinfected; but such an explanation can hardly hold good if one calls to mind the small block culture experiments which have already been described in detail, and remembers that the first sign of sporophore production did not appear until at least three months after infection; and even when typical sporophores did appear, they were only of very small dimensions. Yet another explanation might be urged: since oidium-like cells have been seen among the hyphae in wood vessels, may not these cells be adapted to resist prolonged drought just as spores are? But then again they were not by any means abundant in the dry specimens of rotten wood examined, so it is hardly to be believed that the mycelium, which was in a good fruiting condition within a month of the dried branch being

placed under damp conditions, was developed solely from these structures. This instance of great vitality in mycelium is not without a parallel case, for Falck [1] mentions that horse dung infected with the mycelium of *Coprinus sterquilinus* was capable of infecting other cultures after being kept perfectly dry for a year. Again, the blocks of ordinary mushroom spawn sold in shops are usually quite dry, and probably have been kept so for long periods, and still the mycelium retains its vitality. Since mycelium possesses this power of retaining its vitality, even after four years' drying, it is evidently highly important that timber used for economic purposes should be well tested as to its soundness, and if possible some sterilizing treatment adopted before using, otherwise any access of moisture would cause a further development of the fungus and renewed rotting of the wood. Often in the course of this investigation block after block of apparently sound hard wood, especially birch, had to be discarded, because on being examined microscopically it was found to be already infected. Of course, the sterilizing process would have prevented any of the mycelium developing further, but any blocks thus affected would have been vitiated for microscopic examination afterwards.

Buller [2] has made known the fact that very many of the leathery and woody forms of sporophores, such as *Polyporus*, *Daedalia*, *Fomes*, etc., after prolonged drying, are capable when moistened of reviving and shedding spores again: in some instances, the sporophores which revived had been dry for several years. The sporophores of *Polystictus versicolor* also possess this power of reviving: sporophores which had been dried for sixteen months, and were perfectly hard and rigid, on being thoroughly moistened revived in $3\frac{1}{2}$ hours. And apparently the same sporophore is capable of reviving again and again after drying and becoming quite hard, for several which were tested revived as many as six times. But specimens four years' old, removed from the branch whose mycelium revived, had lost their vitality entirely.

Under natural conditions the hymenial surface of the pileus does not often last longer than a few months owing to the ravages of a little beetle (*Cis boleti*, Scop.), which delights in consuming its substance, whether moist or dry. Even gathered sporophores, unless special care had been taken to pick only perfectly sound ones, after a few months will be found entirely consumed with the exception of the velvety upper surfaces.

The spores also retain their vitality for long periods. Spores

[1] Falck, *l.c.*, p. 317.

[2] Buller, in a communication to the Royal Society, not yet published.

which were kept in the laboratory for eleven weeks always germinated, although drying delayed the germination somewhat longer than the usual period of twenty-four to forty-eight hours: those which had been dried for seventeen weeks would not germinate.

The spores are also capable of germination after exposure to high and low temperatures: those which had been in a temperature of 41° C. for three days germinated in three days, and they also germinated after being exposed for half an hour to a temperature of 75° C, but were not able to survive a temperature of 100° C. After being kept for three days at a temperature of 0° C. in the ice chest of the Chemical Department, spores germinated two days later than those of the same spore deposit kept at ordinary laboratory temperature, but they would not germinate after being frozen for three weeks.

8.—Enzymes.

The life-history of a fungus would be very incomplete without some reference being made to its enzymes, for doubtless the gradual decay which a fungus causes in sound wood is to be attributed to the activities of these secretions, in the preparation of easily assimilable food material for the fungus plant. Although in recent years enzymes have received much attention from many investigators the records of their occurrence in fungi are far from numerous.

By means of the usual tests on an extract of *Polystictus versicolor* the presence of laccase, rennetase, cytase, invertase, diastase, coagulase, ereptase and a fibrin digesting protease was demonstrated. Only negative results were obtained on testing for emulsin, lipase, maltase and hadromase.

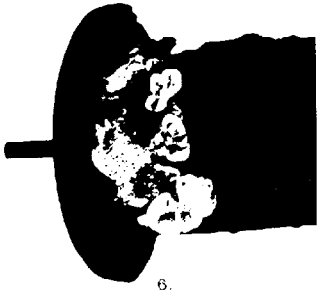
9.—Conclusion.

In conclusion, I must express my thanks to Professor Hillhouse for the kindly assistance he has rendered me in many ways in the course of this work; and also my indebtedness to Professor Buller, both for the subject of this investigation and for the very many helpful suggestions he has given me in carrying it out; and to Professor Adrian Brown for loan of apparatus and material. My thanks are also due to Mr. Herbert Stone for identifying the wood experimental blocks, to Mr. Stoward, M.Sc., for help in the enzyme section of this work, and to Mr. W. B. Grove, M.A., for the identification of some of the fungi.

University Botanical Laboratory,
Birmingham,
March, 1908.

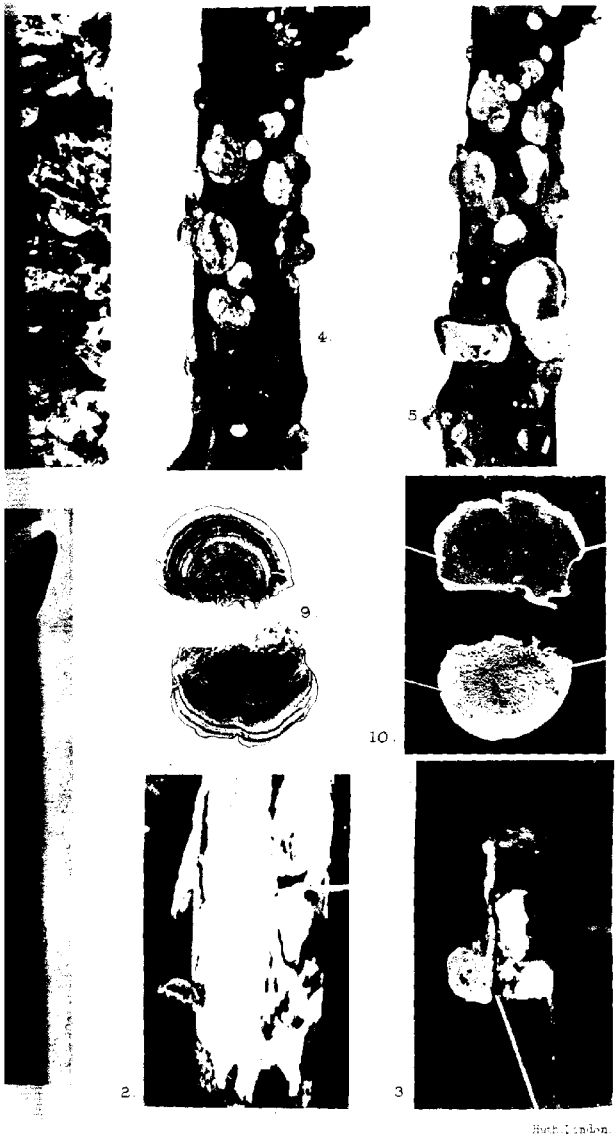
8.

1.



6.

11.



Hutchinson

EXPLANATION OF PLATES I AND II,

Illustrating Miss Jessie S. Bayliss' paper on "The Biology of *Polystictus versicolor* (Fries)."

PLATE I.

Fig. 1.—Sporophores of *Polystictus versicolor* growing on a mountain ash log in Sutton Park, 1907.

Fig. 2.—Sporophore grown from spores on a small block of ash.

Fig. 3.—Hymenial surface of the sporophore in fig. 2: the large hole was made by a small beetle.

Fig. 4.—Large sporophore bosses on a branch which has been kept in a dark room for nine months. No trace of hymenium to be seen.

Fig. 5.—The same branch as in fig. 4, a week after being in the light: hymenial surfaces have developed.

Fig. 6.—Abnormal sporophores formed on a branch while revolving on a clinostat: the cork disc and spindle were used for attaching the branch to the clinostat.

Fig. 7.—Pileus (slightly enlarged) developed on rotten branch from mycelium which had retained its vitality for four years in a desiccated condition: numerous young sporophore bosses are visible.

Fig. 8.—The horizontal rod-like structure is a series of sporophores growing one out of the other.

Fig. 9.—Upper surfaces of fruit bodies of *Polystictus versicolor* showing zoning.

Fig. 10.—Lower surfaces of fruit bodies of *Polystictus versicolor* showing the pores of the hymenial tubes.

Fig. 11.—Culture tube containing a wood block which is partly covered with mycelium and on which a young sporophore boss has developed.

PLATE II.

Fig. 1.—Freshly fallen spores. × 800.

Fig. 2.—Germinating spores after forty-eight hours in tap water. × 800.

Fig. 3.—Germinating spores twenty-four hours later than in fig. 2. × 800.

Fig. 4.—Hyphae from spores grown in malt-gelatine breaking into oidia: the hyphae have liquified the malt-gelatine in their vicinity. × 800.

Fig. 5.—(*a*) Conidia budding from exhausted hyphae. × 1000. (*b*) Germinating conidium with a large glistening drop in the centre.

Fig. 6.—(*a*) Two-celled olive green conidia. (*b*) Germinating conidium. (*c*) Germinating conidium a few days older than (*b*). (*d*) A two-celled conidium surrounded by a rough wall.

Fig. 7.—Transverse section through rotten mountain ash wood. × 800. *a*, *a*, *a*, are vessels blocked with fungus hyphae. *b* is an almost entirely

consumed medullary ray. *c*, *c* are destroyed vessels. *d*, *d*, *d* are walls consumed except for the middle lamella. Corroded walls are everywhere apparent.

Fig. 8.—Tangential section through rotten mountain ash wood *a*, *a*, *a* are nearly consumed medullary rays. *b* is a hypha passing through a pit, *c*, another penetrating a wall. *d* is a large hole made by a fungus hypha. *e*, *e* is a corroded wall. Enlarged pits are very numerous

Fig. 9.—Section shewing swelling of hyphae previous to penetrating walls.

Fig. 10.—Olive green conidial cells and wide hyphae from the black specks in the glycerine culture. × 800.

Fig. 11.—A portion of the hymenial layer showing basidia and spores.

Fig. 12.—*a*, *b*, *c*, and *d* are sections showing successive stages in the development of a sporophore. Natural size.

REVIEWS AND CURRENT LITERATURE.

I.—General Subject.

Howard, L. O.—The Recent Progress and Present Conditions of Economic Entomology. Science, 1907, n.s. vol. xxvi, pp. 769-791.

This is a most interesting review of the progress that has been made since 1894 in economic entomology. To collect the necessary information from all parts of the world must have been no easy task, and whilst we fully agree with Dr. Howard that "official recognition of this science in Great Britain is slight," there is much more work being done than Dr. Howard seems to be aware of. We find no mention of the excellent work of Dr. R. Stewart MacDougall, in Scotland; of the Department of Economic Zoology in the University of Manchester; Mr. Cecil Warburton's work in connection with the Royal Agricultural Society; or that being carried out by The Cooper Research Laboratory.

Morgan, H. A.—The Relation of the Economic Entomologist to Agriculture. Journ. Econ. Entom., 1908, vol. i, pp. 11-15.

Sanderson, E. D.—The Relation of Temperature to the Hibernation of Insects. Journ. Econ. Entom., 1908, vol. i, pp. 56-65, 2 figs.

Westell, W. P.—The Insect Book. Pp. xii. + 120, 36 figs. By R. B. Imisson. London: John Lane. [1908]. Price 3/- net.

This dainty little brochure is one of Mr. Lane's "Country Handbooks" series. At the present time there seems to be a demand for nicely illustrated books, such as this, treating on insects and insect life.

The illustrations are certainly good, but we must confess that we cannot understand anyone who wishes to learn anything about insects turning to such a work as this, when, for a few pence more, he or she can obtain a work like Professor Carpenter's "Insects, their Structure and Life," and possess an excellent and entertaining guide.

We do not say this as in anyway derogatory to Mr. Westell's little work, which is written in an entertaining style, and will no doubt be widely read.

After an introduction, full of interesting facts, the author considers the commonest forms of insects of the garden, the water-side, the woodland, of meadows, heaths, and lanes, and household insects.

W. E. C.

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III.—General and Systematic Biology, and Geographical Distribution.

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Cerva, F. A.—Biologie der *Eilicrinia cordiaria*, Hb. Zeit. f. wiss. Insekten., 1907, Bd. iii, pp. 53-56, 1 fig.

Cholodkovsky, N.—Zur Biologie von *Scardia tessulatella*, Zell. Zeit. f. wiss. Insekten., 1907, Bd. iii, pp. 78-83, 6 fign.

Donisthorpe, H. St. J.—The Life-History, and Occurrence as British of *Lomechusa strumosa*, F. Trans. Entom. Soc. Lond., 1907, pp. 415-420, figs. 1-6.

Eichelbaum, F.—Die Larven von *Cis festivus*, Panz., und von *E. phylus glaber*, Gyll. Zeit. f. wiss. Insekten., 1907, Bd. iii. pp. 25-30, 8 fign.

Escherich, K.—Neue Beobacktungen über *Paussus* in Erythrea. Zeit. f. wiss. Insekten., 1907, Bd. iii, pp. 1-8, 2 fign.

Felt, E. P.—Observation on the Biology and Food Habits of the *Cecidomyiidae*. Journ. Econ. Entom., 1908, vol. i, pp. 18-21.

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Leonardi, G.—Notizie sopra alcune cocciniglie dell' Isola di Giava raccolte dell Prof. O. Penzig. Boll. Lab. Zool., R. Scuola Sup. d'Agric. Portici, 1907, vol. i, pp. 97-116, 38 text figs.

Leonardi, G.—Notizie sopra una cocciniglia degli agrumi nuova per l'Italia (*Aonidiella aurantii*, Mask.). Ibid., pp. 117-134, 20 text figs.

Leonardi, G.—Contribuzione alla conoscenza delle cocciniglie italiane. Ibid., pp. 135-169, 61 text figs.

Martelli, G.—Contribuzione alla biologia della *Pieris brassicae*, L., e di alcuni suoi parassiti ed iperparassiti. Ibid., pp. 170-224, 12 text figs.

Martelli, G.—Di alcuni parassiti dell' *Ocnogyna baeticum*, Ramb., osservati nei dintorni di Catanzaro. Ibid., pp. 225-230.

Masi, L.—Contribuzioni alla conoscenza sei Calcididi italiani. Ibid., pp. 231-295, 47 text figs.

Masi, L.—Contribuzioni alla conoscenza degli insetti Dannosi all' Olivio e di quelli che con essi hanno rapporto. Ibid., 1908, vol. ii, pp. 185-194, 6 text figs.

Mokrzecki, S.—Naturgeschichte einer Halmeule (*Tapinostola maculosa*, Hb.). Zeit. f. wiss. Insekten., 1907, Bd. iii, pp. 87-92, 6 fign.

Newell, W.—Notes on the Habits of the Argentine or "New Orleans" Ant, *Iridomyrmex humilis*, Mayr. Journ. Econ. Entom., 1908, vol. i, pp. 21-34.

Ransome, B. H.—Notes on Parasitic Nematodes, including descriptions of new Genera and Species, and observations on life-histories. U.S. Dept. Agric., Bur. of An. Indus., Circ. 116, 1907, pp. 1-7.

The new species are *Trichostrongylus capricola*, *Ostertagia* (n. gen.) *trifurcata*, *marshalli*, and *occidentalis*, *Cooperia* (n. gen.) *pectinata*, and *Nematodirus* (n. gen.), the *Strongylus filicollis* of Rudolphi being the type.

Schreiner, J. T.—Zwei neue interessante Parasiten der Apfelmade *Carpocapsa pomonella*, L. Zeit. f. wiss. Insekten, 1907, Bd. iii, pp. 217-220, 1 fig.

Scott, Hugh.—On a large series of *Nycteribiidae*, parasitic Diptera, from Ceylon. Trans. Entom. Soc. Lond., 1907, pp. 421-428.

Silvestri, F.—Descrizione di un novo genere d'insetti apterigoti rappresentante di un novo ordine. Boll. Lab. Zool., R. Scuola Sup. d'Agric. Portici, 1907. vol. i, pp. 286-311, 18 text figs.

Silvestri, F.—Descrizione e prime notizie biologische dell' Ecofillembio dell' Olivio (*Oecophyllembius neglectus*, Silv.). Ibid., 1908, vol. ii, pp. 195-216, 23 text figs.

Smith, J. B. Cultivation and Susceptibility to Insect Attack. Journ. Econ. Entom., 1908, vol. i, pp. 15-17.

Williamson, E. B.—The Dragonflies (Odonata) of Burma and Lower Siam—II. Sub-families *Cordulegasterinae*, *Chlorogomphinae*, and *Gomphinae*. Proc. U.S. Nat. Mus., 1907, vol. xxii, pp. 267-317, 39 text figs.

IV.—Agriculture and Horticulture.

Bedford, The Duke of, and Pickering, S. U.—Eighth Report of the Woburn Experimental Fruit Farm. Pp. iv + 129 and three appendices. London: The Amalgamated Press, Ltd., 1908. Price 2s. 6d.

The work here detailed is of great interest and value, but it is most unfortunate that the authors should write as if they were the only experimenters with insecticides and fungicides; that they were always right and everyone else always wrong. Indeed one would imagine, did one not know otherwise, that His Grace the Duke of Bedford and Mr. Pickering alone were the only people who were permitted to investigate such matters.

Whilst most of the experiments are interesting, many of the results are scarcely practicable, and a few are practically useless. The "if's" and "buts" are very numerous, and, as we have had occasion to previously remark with reference to earlier Reports, this badly wants editing.

L. G.

Cathcart, C. S.—Analyses of Paris Green. New Jersey Agric. Exp. Stat., Bull. 205, 1907, pp. 1-9.

Chittenden, F. H.—An Injurious North American species of *Apion*, with notes on related forms. U.S. Dept. Agric., Bur. of Entom., Bull. No. 64, pt. iv, 1908, pp. 29-32, fig. 7.

Evans, J. B. P.—Peach Leaf Curl. *Exoascus deformans*, Fckl. Transv. Agric. Journ., 1908, vol. vi, pp. 259, 260, 2 plts.

Hinds, W. E.—Some Factors in the Natural Control of the Mexican Cotton Boll Weevil. U.S. Dept. Agric., Bur. of Entom., Bull. No. 74, 1907, pp. 1-79, plts. i-iv, and 2 figs.

The author discusses the influence of temperature and moisture, cultural conditions, and of heat, ants, and parasites.

Howard, C. W.—The Scale Insects of Citrus Trees. Transv. Agric. Journ., 1908, vol. vi, pp. 265-277, plts. 22, 23, 2 text figs.

Howard, L. O., and Chittenden, F. H.—The Catalpa Sphinx. (*Ceratomia catalpae*, Bdv.). U.S. Dept. Agric., Bur. of Entom., Circ. No. 96, 1907, pp. 1-7, 2 figs.

Howard, L. O., and Chittenden, F. H.—The Bagworm. (*Thyridopteryx ephemeraeformis*, Haw.). U.S. Dept. Agric., Bur. of Entom., Circ. No. 97, 1908, pp. 1-10, 11 figs.

Howell, A. H.—The Relation of Birds to the Cotton Boll Weevil. U.S. Dept. Agric., Biol. Sur., Bull. No. 29, 1907, pp. 1-31, 1 plt., and 6 text figs.

Hunter, W. D., Newell, W., and Pierce, W. D.—The Insect Enemies of the Boll Weevil. State Crop Pest Comms. of Louisiana, Circ. No. 20, 1907, pp. 1-7, 3 figs.

Kellogg, V. L.—The Mallophagan Parasites of the Kea. Psyche, 1907, vol. xiv, pp. 122, 123.

Lantz, D. E.—An Economic Study of Field Mice (Genus *Microtus*). U.S. Dept. Agric., Biol. Surv., Bull. No. 31, pp. 1-64, plts. i-viii, 3 figs.

Lefroy, H. M.—Practical Remedies for Insect Pests. Agric. Journ. India, 1907, vol. ii. pp. 356-363.

Lefroy, H. M.—The Tse-Tse Fly in India. Ibid., pp. 374-376.

Marlatt, C. L.—The White Ant. (*Termes flavipes*, Koll.). U.S. Dept. Agric., Bur. of Entom., Circ. No. 50, rev. ed. 1908, pp. 1-8, 4 figs.

Pierce, W. D.—Studies of Parasites of the Cotton Boll Weevil. U.S. Dept. Agric., Bur. of Entom., Bull. No. 73, 1908, pp. 1-63, plts. i-iii, and 6 figs.

Quaintance, A. L.—The Lesser Apple Worm (*Enarmonia prunivora*, Walsh). U.S. Dept. Agric., Bur. of Entom., Bull. No. 68, pt.v, 1908, pp. 49-60, plt. vii, 1 text fig.

Quayle, H. J.—Insects Injurious to the Vine in California. Calif. Univ. Agric. Exp. Stat., 1907, Bull. No. 192, pp. 99-140, 24 text figs.

Reh, L.—Insektenfrass au Kakao-Bohnen. Zeit. f. wiss. Insekten., 1907, Bd. iii, pp. 21-25.

Shear, Ch.—Cranberry Diseases. U.S. Dept. Agric., Bur. of Plant Indus., Bull. No. 110, 1907, pp. 1-64, plts. i-vii.

The four chief fungus diseases here described in great detail are scald caused by *Guignardia vaccinii;* rot caused by *Acanthorhynchus vaccinii;* anthracnose, caused by *Glomerella rufomaculans vaccinii;* and hypertrophy, due to *Exobasidium oxycocci.*

The first three mentioned diseases have heretofore been confused and considered as one.

Short notes are given on numerous other less important fungi attacking the fruit, stems, and leaves of the cranberry.

Voorhees, E. B., and Others.—Some Chemical and Bacteriological Effects of Liming. New Jersey Agric. Exp. Stat., Bull. 210, 1907, pp. 1-79.

Voorhees, E. B., and Lipman, J. G.—A Review of Investigations in Soil Bacteriology. U.S. Dept. Agric., Off. Exp. Stat., Bull. 194, 1907, pp. 1-108.

V.—Forestry.

VI.—Fisheries.

VII.—Medicine.

Blanchard, R.—Zoology and Medicine. Ann. Rpt. Smiths. Inst. for 1906. Washington: 1907, pp. 439-452.

Hamer, W. H.—Report by the Medical Officer presenting a report by Dr. Hamer, Medical Officer (General Purposes), on the extent to which the fly nuisance is produced in London by accumulations of offensive matter. 10 pp., 2 figs., and 3 diagrams. Printed for the London County Council (Public Health Committee). London: P. S. King and Son, 1908. Price 3d.

Dr. Hamer has set an excellent example to his fellow medical officers in the report before us. In this country local authorities will not take action unless they are confronted with indisputable evidence as to the presence and cause of a nuisance, and the production of such a report as this will have more influence than any number of conclusions which one may deduce from the study of the bionomics of flies.

In spite of the fact that 1907 was a bad year for flies, Dr. Hamer clearly shows that the fly nuisance is aggravated by the presence of accumulations of horse manure and of other refuse, and that the influence of such deposits may be appreciable at a distance of over two hundred yards; at a less distance it is very manifest. The lesson to be deduced from this is clear—refuse should not be deposited after collection in the proximity of houses not even for a short time, the disposal of the refuse

should be direct from the collecting cart to the railway truck or canal barge which takes it away.

In discussing the relation of flies to summer diarrhoea and enteric fever, Dr. Hamer comes to the conclusion that in this country the facts at present ascertained do not enable us to form a definite opinion. The conclusion indicates the path of investigation which we should wish those medical officers of health with the facilities to follow. Statistics and curves are interesting, but the actual investigation of individual cases is much more important. How much evidence of the greatest importance could be adduced if certain cases were carefully studied by discovering the nidus of the flies, careful bacteriological examination of their feet and of isolated faeces such as one finds in unsanitary quarters; if these and other factors were taken into consideration, the results which would accrue would well repay the inevitable labour which accompanies such investigations.

We would recommend this report to all interested in the fly question, and hope similar investigations will be taken up by other medical officers, not only concerning the actual sources of attraction for flies, but also a study of their breeding places, as the results of such investigations would make it difficult for apathetic local authorities to refuse to take the necessary steps to remedy the evil.

C. Gordon Hewitt.

VIII.—Animal Diseases.

Carpenter, Geo. H., and Steen, John W.—The Warble-Fly. Experiments on Cattle as to its treatment and life history. Journ. Dept. of Agric. Ireland, 1908, vol. viii, pp. 227-246, 3 figs.

This is a most interesting paper, and details a very careful inquiry, although the practical outcome leaves us pretty much in the same position. The authors conclude "that farmers and stock-owners should concentrate their energies on destroying the maggots while they are in the warbles on the beast's backs during the winter and spring," either by squeezing out the maggots, or by applying some poisonous or greasy substance to the warble-hole.

Hooker, W. A.—A Review of the present knowledge of the Role of Ticks in the Transmission of Disease. Journ. Econ. Entom., 1908, vol. i, pp. 65-76.

Phillips, E. F.—Wax Moths and American Foul Brood. U.S. Dept. Agric., Bur. of Entom., Bull. No. 75, pt. ii, 1907, pp. 19-22, plts. i-iii.

The author shows that two wax moths, *Galleria mellonella* and *Achroia grisella*, do not eat the scales formed from the larvae which have

died of American foul brood. It is clear, therefore, that infectious material in a colony dying of this disease remains even after the comb is destroyed.

Phillips, E. F.—Bee Diseases: A Problem in Economic Entomology. Journ. Econ. Entom., 1908, vol. i, pp. 102-106.

Reynolds, M. H., and Beebe, W. L.—Dissemination of Tuberculosis by the manure of Infected Cattle. Univ. Minn. Agric. Exp. Stat., Vet. Div., Bull. No. 103, 1907, pp. 39-62, 8 figs.

Theiler, A.—The Prevention and Eradication of Stock Diseases in South Africa. Transv. Agric. Journ., 1908, vol. vi, pp. 217-233, 1 plt.